Tom Vance

GEOPHYSICAL SURVEY
GROUND WATER EVALUATION
MAUNA KEA PROPERTIES

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GROUND WATER EVALUATION
MAUNA KEA PROPERTIES

Prepared For:

Mauna Kea Properties
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Kohala Coast, HI 96743

Prepared By:

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(BGI Project #90039)

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Appendix A - Principles of TDEM

Attachment - Resistivity Curves and Data Sheets

1.0 INTRODUCTION

This report contains the results of a geophysical survey for ground water resource evaluation on the Mauna Kea Properties area on the Island of Hawaii. The work was performed for Mauna Kea Properties (MKP) by Blackhawk Geosciences, Inc. (BGI) from July 27 through July 30, 1990.

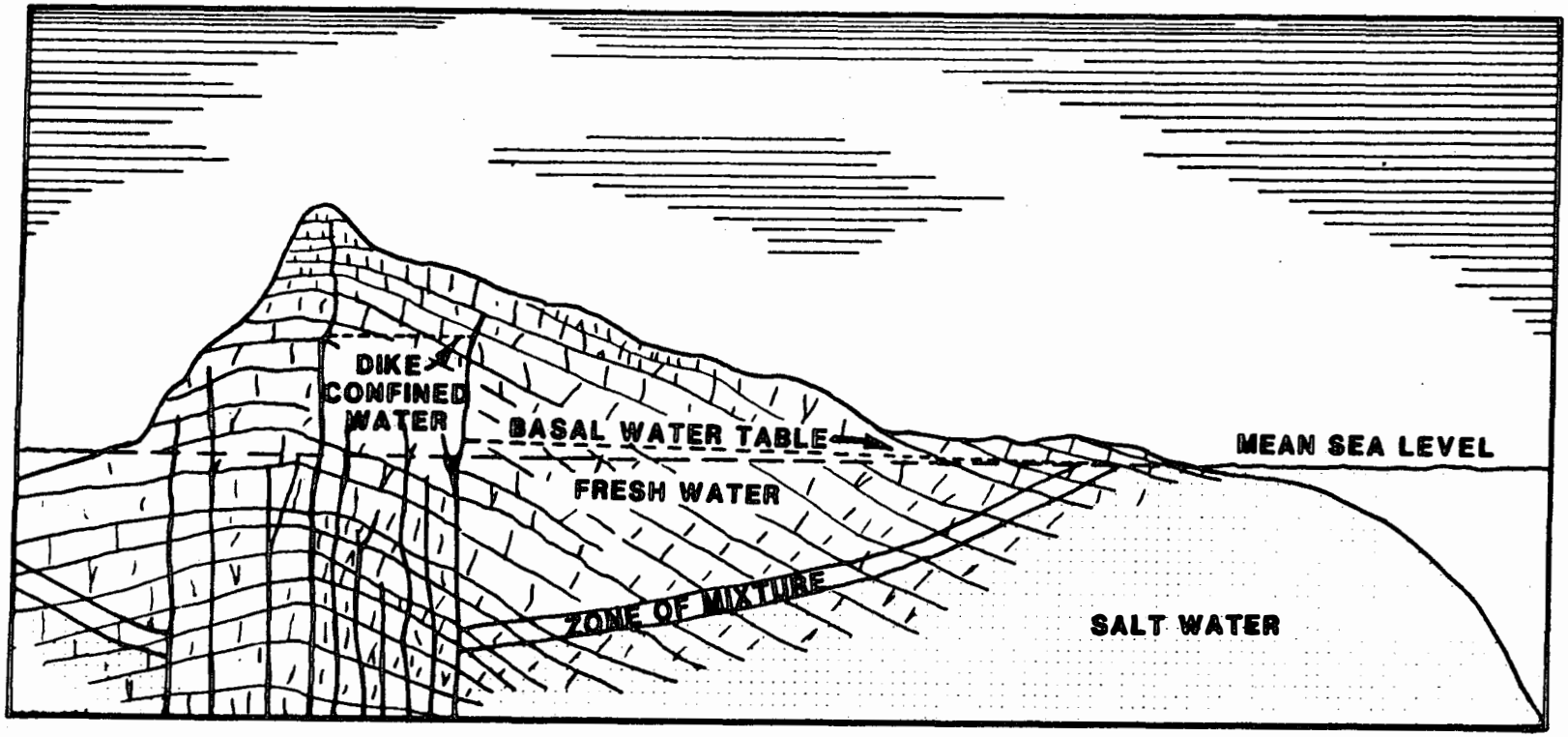
The general objective of the geophysical survey at the MKP area was to assist in characterizing the hydrologic regime in the study area. The main objectives for geophysical surveys for ground water evaluations on volcanic islands are illustrated in Figure 1-1. The volcanic rocks are generally highly permeable and this allows rainwater to percolate with little impedance directly downward through the island mass. The fresh water in these island settings is generally found in two environments:

1. Dike-confined waters. Typically, above the rift zone, intrusive dikes originating from a magma source below can form ground water dams, and behind these natural dams significant quantities of ground water can be stored.

2. Basal fresh water. The high permeability of the volcanic rocks allows sea water to enter freely under the island, and a delicate balance is reached where a lens of fresh water floats on sea water. In cases of hydrostatic equilibrium, the Ghyben-Herzberg relation states that for every foot of fresh water head above sea level there will be about 40 ft of fresh water below sea level.

At MKP, ground water was expected to occur mainly as basal fresh water. The impetus for using geophysics is that the cost of a geophysical sounding is about one-thousandth the cost of completing a well at elevations above 1,000 ft. Geophysical surveys, combined with other hydrogeologic information, are used to provide optimum locations for well placement and well completion depths.

The geophysical method employed was time domain electromagnetic (TDEM) soundings. This method was selected because it has proven effective in prior surveys in similar settings in Hawaii.



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SCHEMATIC HYDRO-GEOLOGIC CROSS SECTION

MAUNA KEA PROPERTIES

PROJECT NO: 90039 FIGURE 1-1

2.0 LOGISTICS AND DATA ACQUISITION

2.1 GENERAL

The TDEM survey was accomplished by a crew consisting of two BGI personnel and a local temporary field helper. The location of the geophysical survey points were determined during consultation with Tom Nance of Tom Nance Water Resources Engineering.

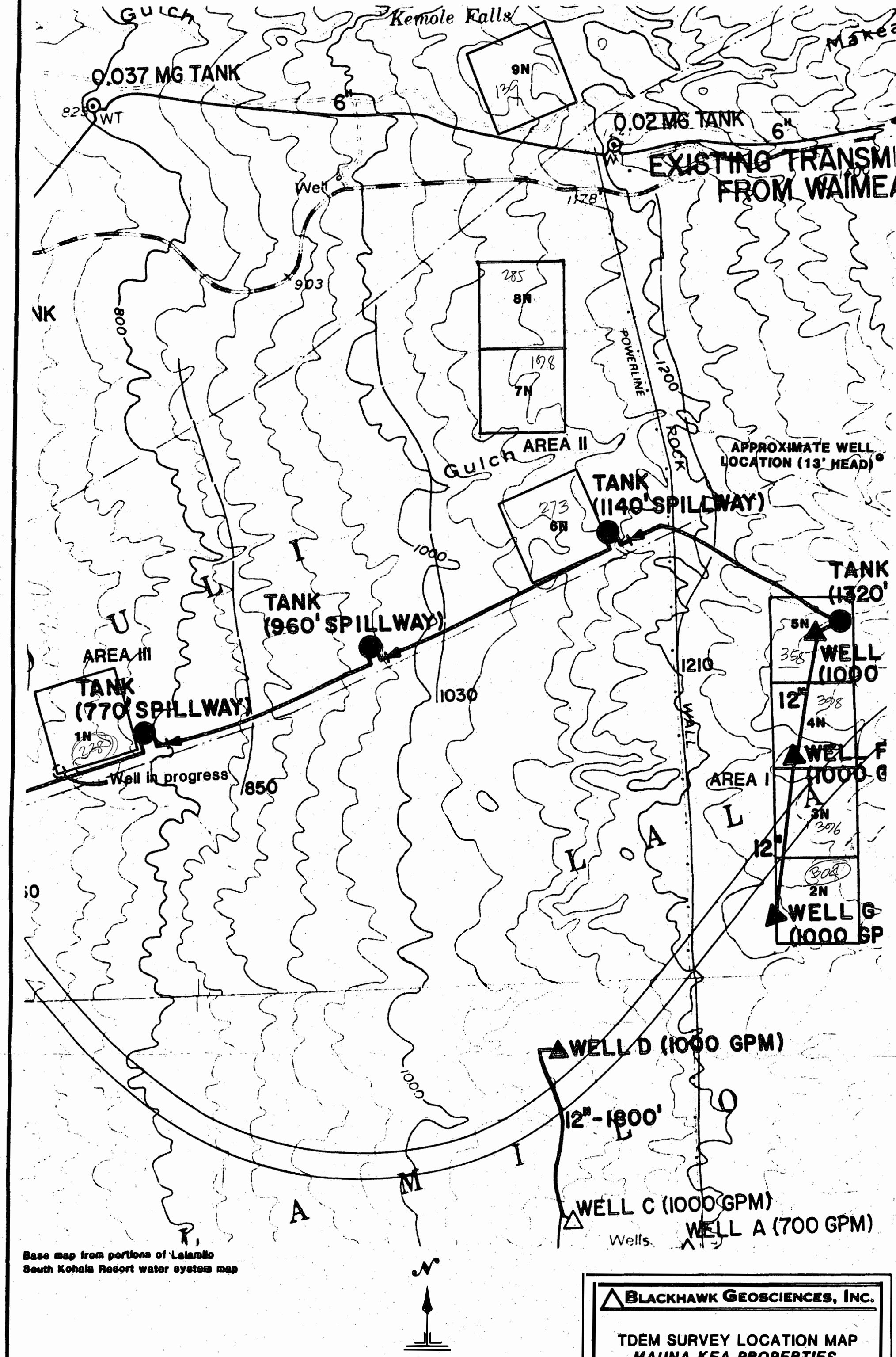
During the four days of field work, 9 soundings were completed. A daily log of field activity is given in Table 2-1. The location of the soundings for MKP are shown in Figure 2-1.

2.2 PROCEDURES

The Geonics EM-37 TDEM system was utilized on this survey. The system basically consists of a transmitter and a receiver. The transmitter loop is constructed of 10 to 12 gauge insulated copper wire. The wire is laid on the ground surface in a square loop varying in size, depending upon the required depth of investigation (larger loop sizes for deeper measurement). For the MKP area loop sizes were 1,000 ft on each side. A transmitter and motor generator are connected into the loop at one corner. A time-varying current is pulsed through the wire at two different base frequencies. The TDEM receiver measures and records the decay of the vertical magnetic field through a receiver coil placed at the center of the non-grounded transmitter loop. Receiver coils with effective areas of 100 m^2 and 1,000 m^2 were utilized at base frequencies of 3 Hz and 30 Hz. During data acquisition numerous transient decays are collected with the receiver for each sounding. Readings were acquired at several receiver gains with opposite receiver polarities for each sounding location. The readings were stored in a DAS-54 solid state data logger, and were nightly transferred to a Compaq computer for processing. A technical brief is given in Appendix A which describes and illustrates the principles of TDEM.

Table 2-1. Daily log of field activity

Date (1990)	Activity
August 23	Mobilize to the Island of Hawaii.
August 24	Site check, client meeting, measurement sounding 1.
August 25	Measurement soundings 2, 3, 4 and 5.
August 26	Measurement soundings 6 and 7.
August 27	Measurement soundings 8 and 9.
August 28	Meeting with MKP's water resource consultant, Tom Nance.
August 29	Demobilize to Golden, CO.



Base map from portions of Lalamilo
South Kohala Resort water system map

1000 0 1000 FT

BLACKHAWK GEOSCIENCES, INC.

TDEM SURVEY LOCATION MAP
MAUNA KEA PROPERTIES

PROJECT NO: 90039 Figure 2-1

3.0 DATA PROCESSING

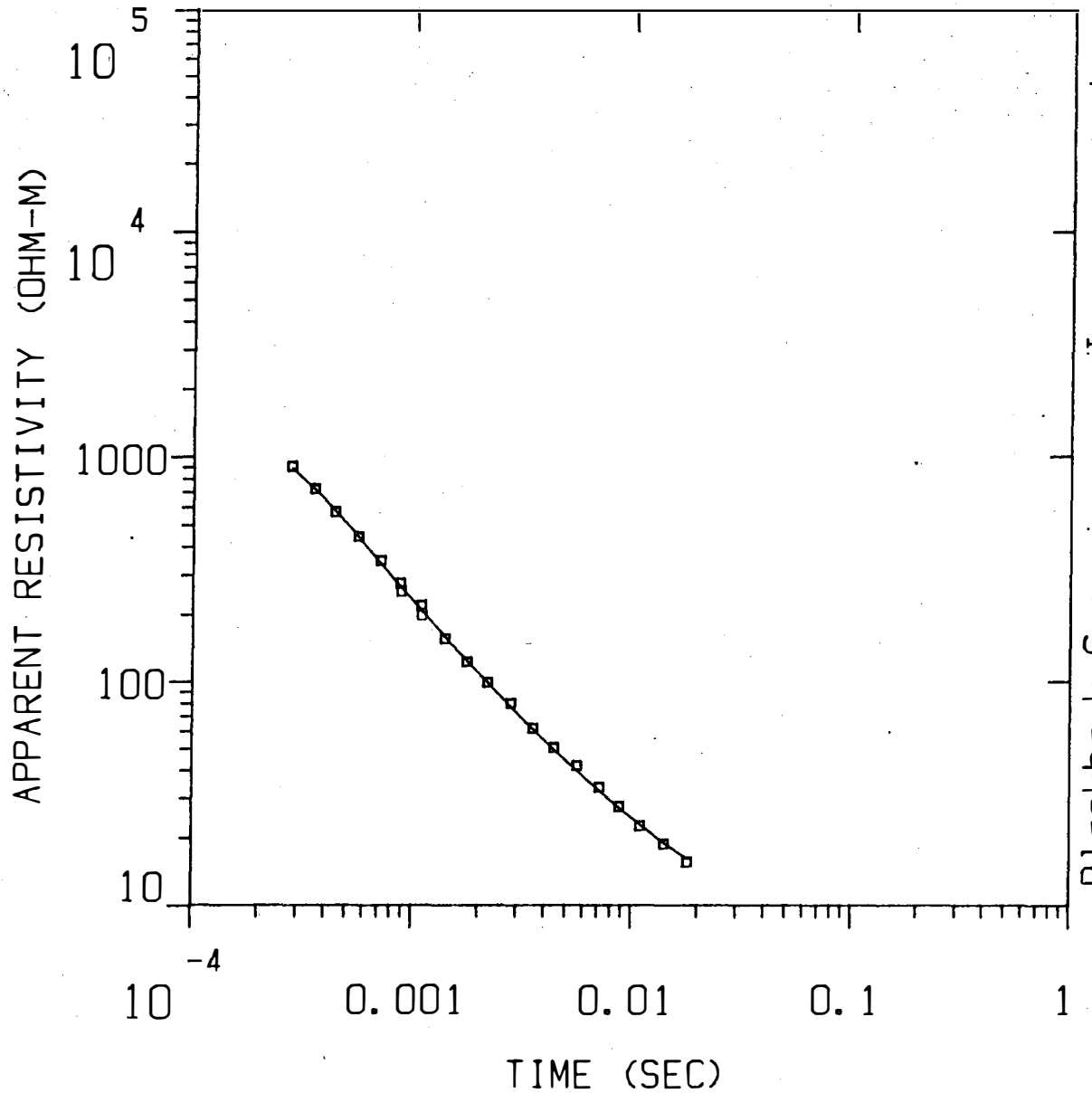
The field data acquired each day was transferred from the DAS-54 data logger to a microcomputer. The data for each sounding location is edited and combined (both 3 Hz and 30 Hz frequencies) to produce a transient decay curve. This decay curve is transformed into an apparent resistivity curve, which is entered into an Automatic Ridge Regression Transient Inversion Program. From the apparent resistivity curve a one-dimensional model of resistivities and thicknesses is calculated.

The inversion program requires an initial estimate of the geoelectric section, including the number of layers, and the resistivities and thicknesses of each of the layers. The program then adjusts these parameters so that the model curve converges to best fit the curve formed by the field data set. The inversion program does not change the total number of layers within the model, but allows all other parameters to float freely.

An example data set is given in Figures 3-1 and 3-2 for sounding 1. Figure 3-1 shows the measured data points (in terms of apparent resistivity) superimposed on a solid line. The solid line represents the computed behavior of the true resistivity layering shown on the right. Figure 3-2 lists in column 4 the error between measured and computed data in each time gate.

The apparent resistivity curves and data sheets for all soundings are contained in the attachment.

MK1ED MODEL:



401.
OHM-M

289. M

3.12
OHM-M

Blackhawk Geosciences, Incorporated

% ERROR: 4.29
CALIBRATION: 1
OFFSET: 152. M
RAMP: 165.0

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EXAMPLE APPARENT RESISTIVITY CURVE

MAUNA KEA PROPERTIES

PROJECT NO: 90039 **Figure 3-1**

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		219.5	720.0		
401.19	288.9	-69.5	-227.9	0.7	0.7
3.12					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	2.80E-04	9.04E+02	8.93E+02	1.193	
2	3.55E-04	7.18E+02	7.21E+02	-0.347	
3	4.43E-04	5.69E+02	5.81E+02	-2.012	
4	5.64E-04	4.40E+02	4.43E+02	-0.704	
5	7.13E-04	3.45E+02	3.38E+02	2.263	
6	8.81E-04	2.75E+02	2.67E+02	2.861	
7	8.90E-04	2.52E+02	2.64E+02	-4.432	
8	1.10E-03	2.19E+02	2.10E+02	4.522	
9	1.10E-03	1.98E+02	2.09E+02	-5.350	
10	1.40E-03	1.56E+02	1.60E+02	-2.615	
11	1.77E-03	1.22E+02	1.24E+02	-1.574	
12	2.20E-03	9.86E+01	9.90E+01	-0.391	
13	2.80E-03	7.97E+01	7.72E+01	3.310	
14	3.55E-03	6.16E+01	6.13E+01	0.581	
15	4.43E-03	5.04E+01	4.96E+01	1.632	
16	5.64E-03	4.18E+01	3.98E+01	4.931	
17	7.13E-03	3.35E+01	3.25E+01	2.969	
18	8.81E-03	2.75E+01	2.72E+01	1.056	
19	1.10E-02	2.26E+01	2.30E+01	-1.919	
20	1.41E-02	1.88E+01	1.91E+01	-1.530	
21	1.80E-02	1.56E+01	1.62E+01	-3.523	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 21 DATA POINTS, RAMP: 165.0 MICROSEC, DATA: MK1ED
2707 001N 001N Z OPR XTL L 7 10+100
Ch.21 = 0.165 Ch.22 = 0.89 Ch.23 = 15.5 Ch.24 =
RMS LOG ERROR: 1.82E-02, ANTILOG YIELDS 4.2881 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	T 1
P 1	1.00		
P 2	0.00	1.00	
T 1	0.00	0.00	1.00

BLACKHAWK GEOSCIENCES, INC.

EXAMPLE DATA TABLE
MAUNA KEA PROPERTIES

PROJECT NO: 90039 **Figure 3-2**

4.0 INTERPRETATION RESULTS

4.1 GENERAL

The primary objective of the TDEM survey is to determine the elevation of the salt water interface. This information is obtained by inversion of TDEM data into one-dimensional profiles of resistivities and thicknesses (geoelectric section). The translation of the geoelectric section into meaningful hydrogeologic information uses prior information obtained from surveys in the south Kohala region and elsewhere. This information includes:

(1) In the geologic setting of this portion of the Island of Hawaii, the volcanic rocks saturated with salt water will generally have resistivities less than 10 ohm-m and usually less than 5 ohm-m.

(2) Dry volcanics and those saturated with fresh/brackish water can have very high resistivities (greater than 400 ohm-m).

(3) Comparison of TDEM soundings adjacent to wells have been in good general agreement with well hydrostatic head measurement in most cases using the Ghyben-Herzberg relation.

Where a very conductive layer (less than 10 ohm-m) is detected below sea level, this layer is interpreted to be caused by salt water saturated volcanics. Static water levels (heads) can be calculated from the elevation of the top to the salt water interface by using the Ghyben-Herzberg relation. An illustration of the Ghyben-Herzberg relation is given in Figure 4-1. This relation assumes hydrostatic equilibrium and may not apply in close proximity to major geologic structures (rifts, dikes, altered zones, etc.) which act to dam ground water flow.

Geoelectric cross-sections were constructed for two areas where a series of measurements were collected reasonably close together. A one-dimensional resistivity section also is shown for sounding 1 near the well being constructed at about 700 ft elevation. Its location is designated as Area III on Figure 2-1.

4.2 RESULTS AREA I

Four soundings were collected in this area around 1,300 ft elevation. The data were matched to two-layer resistivity models. It is inferred from these geoelectric sections that the top of the salt water interface occurs at elevations ranging from -304 to -398 ft with calculated heads varying from 7.5 ft to 10 ft. A geoelectric and hydrogeologic cross-section through the

center of the four soundings is given in Figure 4-2. A well nearby has a reported head of about 13 ft (Fig. 2-1) (personal communications with Tom Nance).

4.3 GEOELECTRIC CROSS-SECTION AREA II

Four soundings were collected in this area around the 1,100 to 1,160 ft elevation. Again, the data were matched to two-layer resistivity models from which elevations of salt water interfaces ranging from -139 to -273 ft elevation are inferred. A geoelectric and hydrogeologic section through the center of the four soundings is given in Figure 4-3.

4.4 SOUNDING 1 - AREA III

Again this sounding was fitted to a two-layer resistivity model, resulting in an interpretation with the elevation of the salt water interface at -228 ft. The sounding is located near a well being drilled at the time of survey. The geoelectric and hydrogeologic section of this sounding is shown in Figure 4-4.

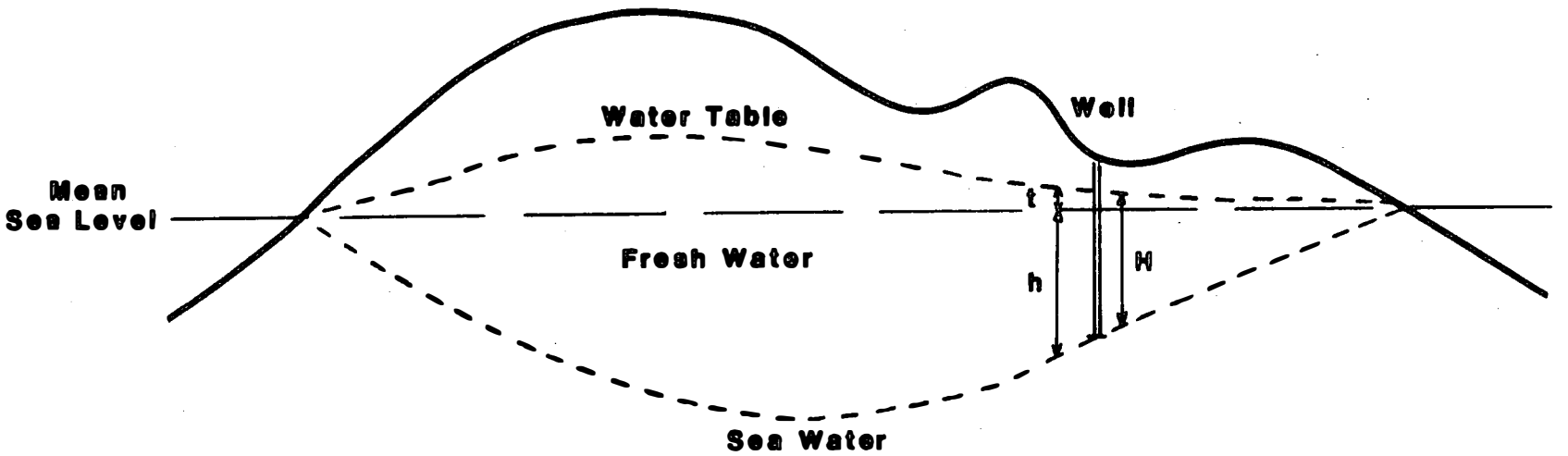
4.5 SUMMARY OF RESULTS

Table 4-1 shows the sounding number, surface elevations, and interpreted elevations of the top to the basal conductive layer (the fresh-brackish/salt water interface). Heads have been calculated using the Ghyben-Herzberg relationship.

Table 4-1. Surface elevations of TDEM station and elevation of top to saline water

Sounding #	Elevation	Elevation of Conductive Layer (Top to Saline Water)	Calculated Head, from Ghyben-Herzberg*
1	720	-228	5.7
2	1300	-304	7.6
3	1320	-396	9.9
4	1300	-398	10.0
5	1320	-358	9.0
6	1090	-273	6.8
7	1110	-198	5.0
8	1120	-285	7.1
9	1160	-139	3.5

*Assumes static equilibrium.



$$t = 1/40\ (h)$$

FROM: HERZBERG

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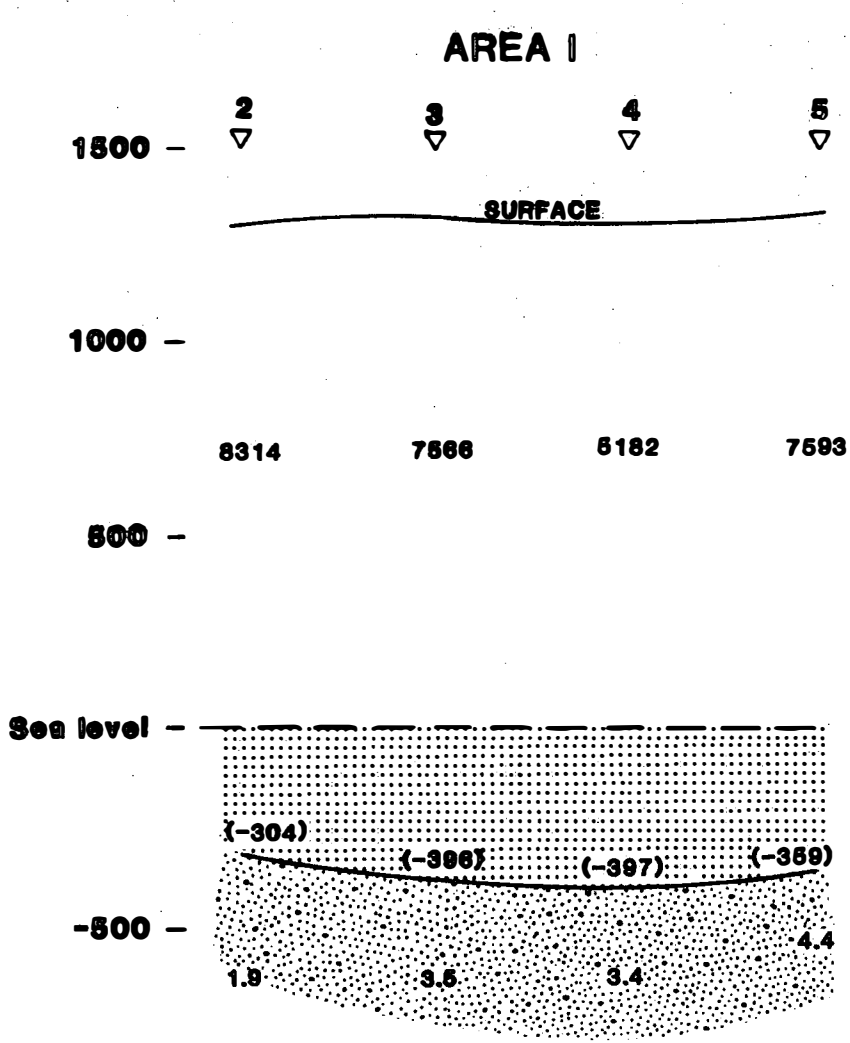
Illustration of the
Ghyben-Herzberg Principle
MAUNA KEA PROPERTIES

PROJECT NO: 90036 Figure 4-1



(-304) Elevation of the conductive layer (Fresh–brackish/salt water interface)

Dry unweathered volcanics

Fresh–brackish water saturated volcanics

Salt water saturated volcanics

500'
Vertical
Horizontal
1000'

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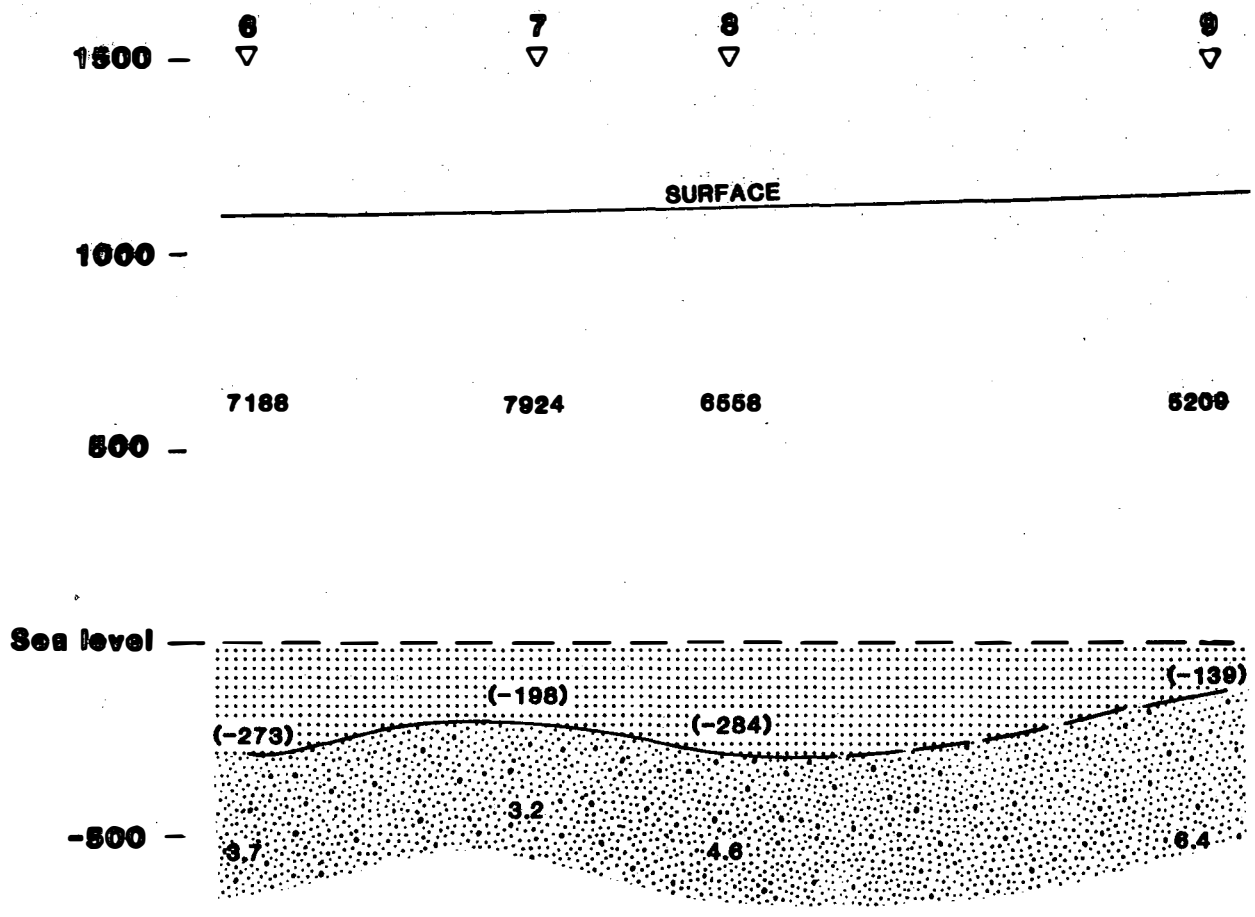
GEOELECTRIC CROSS SECTION
MAUNA KEA PROPERTIES

PROJECT NO 90039 Figure 4–2



(-304) Elevation of the conductive layer (Fresh–brackish/salt water interface)

Dry unweathered volcanics

Fresh–brackish water saturated volcanics

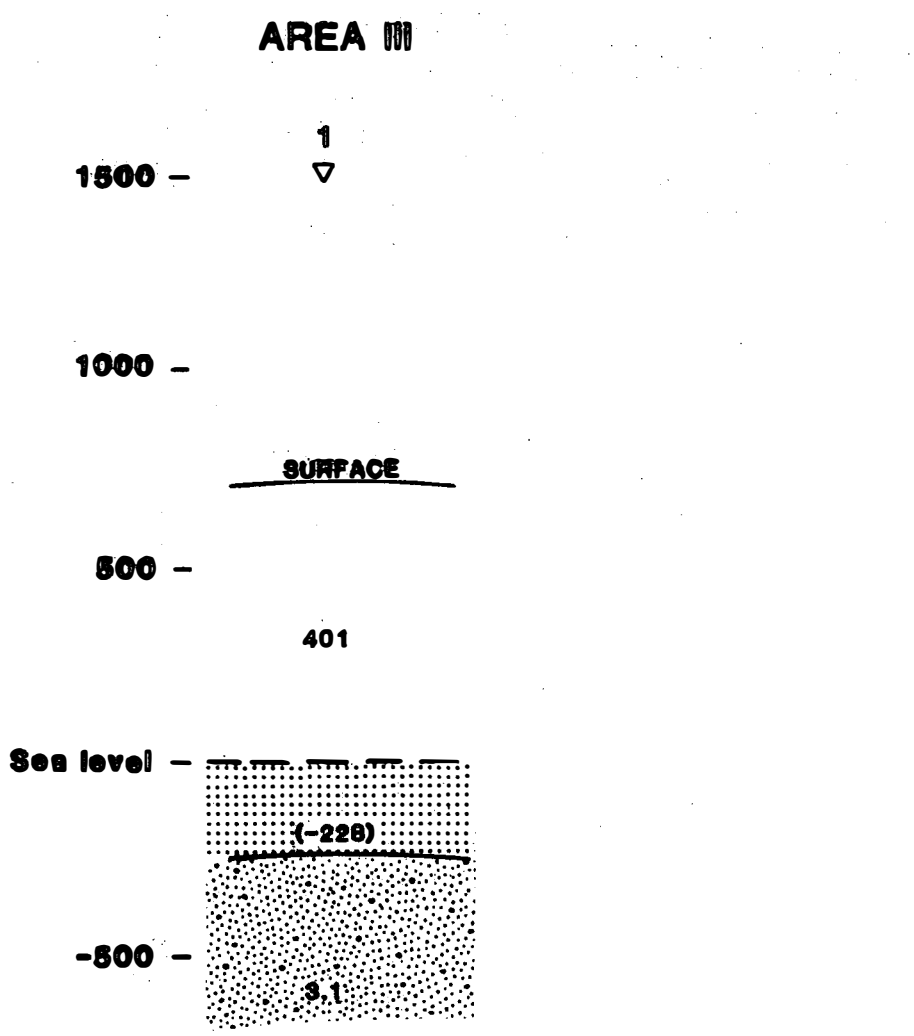
Salt water saturated volcanics

500'
Vertical
Horizontal
1000'

BLACKHAWK GEOSCIENCES, INC.

GEOELECTRIC CROSS SECTION
MAUNA KEA PROPERTIES

PROJECT NO 90038 Figure 4-3

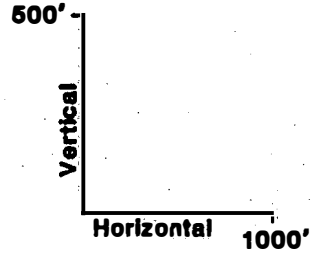


(-304) Elevation of the conductive layer (Fresh–brackish/salt water interface)

Dry unweathered volcanics

Fresh–brackish water saturated volcanics

Salt water saturated volcanics



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GEOELECTRIC CROSS SECTION
MAUNA KEA PROPERTIES

PROJECT NO 90039 Figure 4-4

5.0 CONCLUSIONS AND RECOMMENDATIONS

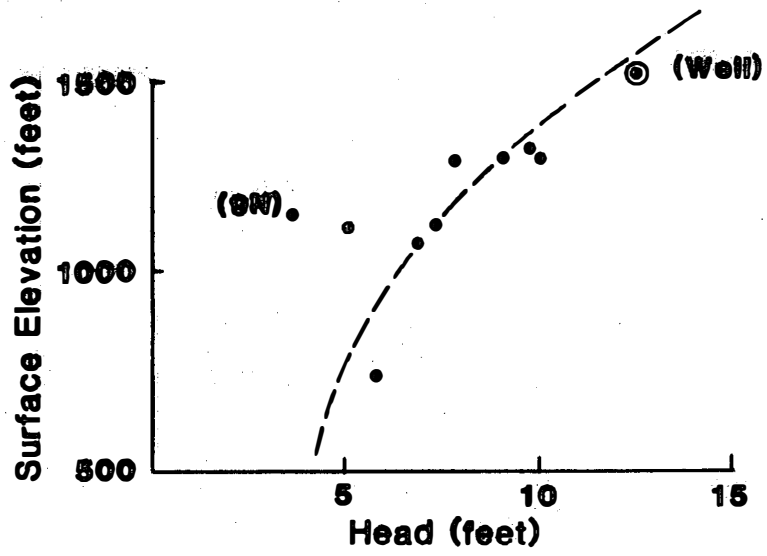
The geoelectric sections derived from TDEM soundings in Areas I, II and III consistently shows a layer with resistivity values less than 5 ohm-m at elevation below sea level. The top of this layer of low resistivity is interpreted to be the interface between fresh/brackish water and highly saline water. The volcanic rock between sea level and top to the saline water interface potentially represents a useable water resource.

The accuracy of the TDEM survey in determining the top to the saline water has previously been evaluated to be $\pm$ 5% of total depth, or about $\pm$ 70 ft at the elevations at which measurements were made on lands of MKP. This translates into an accuracy of about $\pm$ 1.5 ft in head using the Ghyben-Herzberg equation.

The TDEM survey indicates that in the areas surveyed the largest interpreted fresh/brackish water resource occurs at the highest elevation in Area I, where heads between 9 ft and 10 ft are observed. A well located approximately 1,500 ft due north of station 5N, and about 200 ft higher in elevation, is reported to have a head of 13 ft.

On Figure 5-1 surface elevations of TDEM stations are plotted versus head calculated from the Ghyben-Herzberg equation. Also plotted on this figure is the information of the well. The results from sounding 9N shows a major discrepancy in the general trend between surface elevation and observed head. If this is due to a change in local hydrogeology cannot be determined from one data point. A series of measurements along east-west lines would be required to confirm the anomalous behavior observed on station 9N.

In Area III near the present well being constructed, at about 700 ft elevation, a head between 5 ft to 6 ft is expected from the TDEM survey data.



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RELATION BETWEEN
SURFACE ELEVATION AND HEAD
MAUNA KEA PROPERTIES

PROJECT NO: 90039 Figure 6-1

ATTACHMENT

GEOPHYSICAL SURVEY
GROUND WATER EVALUATION
MAUNA KEA PROPERTIES

ATTACHMENT

GEOPHYSICAL SURVEY
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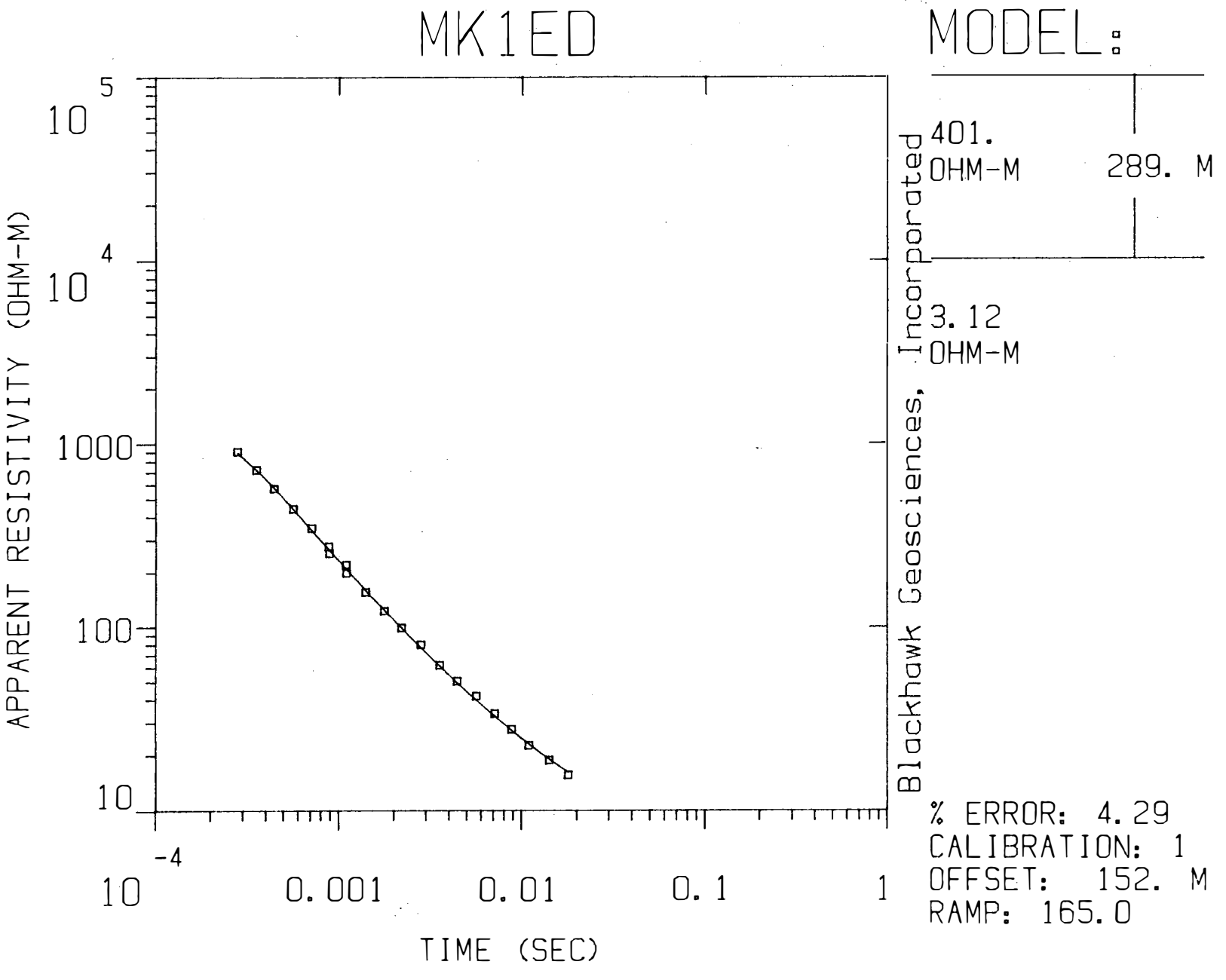

MK1ED
MODEL:
APPARENT RESISTIVITY (OHM-M)
10^5
10^4
1000
100
10
10^-4
0.001
0.01
0.1
1
TIME (SEC)
401.
OHM-M
289. M
3.12
OHM-M
Blackhawk Geosciences, Incorporated
% ERROR: 4.29
CALIBRATION: 1
OFFSET: 152. M
RAMP: 165.0

MK1ED

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		219.5	720.0		
401.19	288.9	-69.5	-227.9	0.7	0.7
3.12					

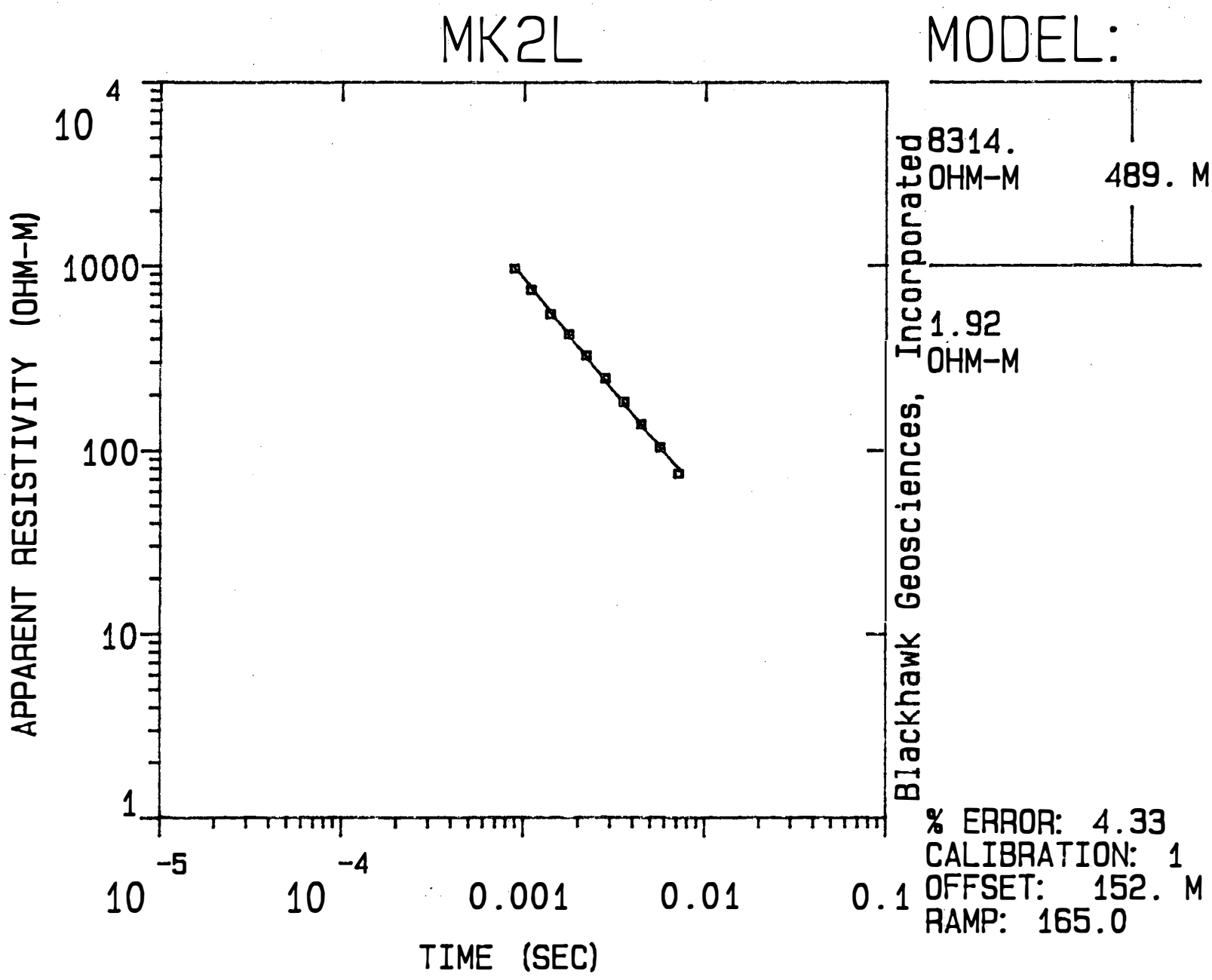
	TIMES	DATA	CALC	% ERROR	STD ERR
1	2.80E-04	9.04E+02	8.93E+02	1.193	
2	3.55E-04	7.18E+02	7.21E+02	-0.347	
3	4.43E-04	5.69E+02	5.81E+02	-2.012	
4	5.64E-04	4.40E+02	4.43E+02	-0.704	
5	7.13E-04	3.45E+02	3.38E+02	2.263	
6	8.81E-04	2.75E+02	2.67E+02	2.861	
7	8.90E-04	2.52E+02	2.64E+02	-4.432	
8	1.10E-03	2.19E+02	2.10E+02	4.522	
9	1.10E-03	1.98E+02	2.09E+02	-5.350	
10	1.40E-03	1.56E+02	1.60E+02	-2.615	
11	1.77E-03	1.22E+02	1.24E+02	-1.574	
12	2.20E-03	9.86E+01	9.90E+01	-0.391	
13	2.80E-03	7.97E+01	7.72E+01	3.310	
14	3.55E-03	6.16E+01	6.13E+01	0.581	
15	4.43E-03	5.04E+01	4.96E+01	1.632	
16	5.64E-03	4.18E+01	3.98E+01	4.931	
17	7.13E-03	3.35E+01	3.25E+01	2.969	
18	8.81E-03	2.75E+01	2.72E+01	1.056	
19	1.10E-02	2.26E+01	2.30E+01	-1.919	
20	1.41E-02	1.88E+01	1.91E+01	-1.530	
21	1.80E-02	1.56E+01	1.62E+01	-3.523	

R: 152. X: 0. Y: 152. DL: 305. REQ: 169. CF: 1.0000
TDHZ ARRAY, 21 DATA POINTS, RAMP: 165.0 MICROSEC, DATA: MK1ED
2707 001N 001N Z OPR XTL L 7 10+100
Ch.21 = 0.165 Ch.22 = 0.89 Ch.23 = 15.5 Ch.24 =
RMS LOG ERROR: 1.82E-02, ANTILOG YIELDS 4.2881 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	1.00		
P 2	0.00	1.00	
T 1	0.00	0.00	1.00
	P 1	P 2	T 1


MK2L
MODEL:
8314.
OHM-M
489. M
1.92
OHM-M
APPARENT RESISTIVITY (OHM-M)
10 4
1000
100
10
1
10 -5
10 -4
0.001
0.01
0.1
TIME (SEC)
Blackhawk Geosciences, Incorporated
% ERROR: 4.33
CALIBRATION: 1
OFFSET: 152. M
RAMP: 165.0

MK2L

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		396.2	1300.0		
8314.21	488.9	-92.7	-304.2	0.1	0.1
1.92					

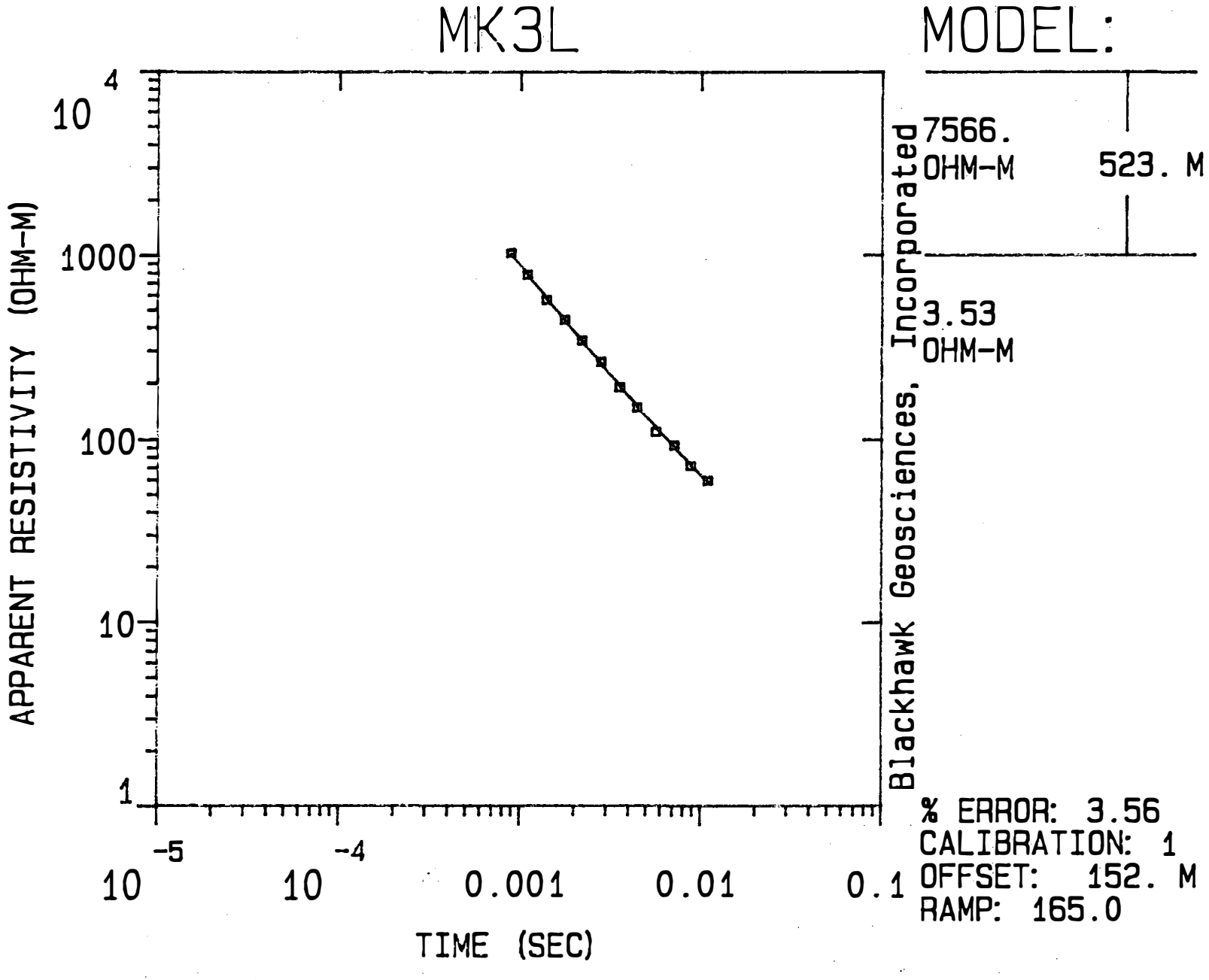
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-04	9.61E+02	9.84E+02	-2.334	
2	1.10E-03	7.35E+02	7.51E+02	-2.146	
3	1.40E-03	5.40E+02	5.54E+02	-2.422	
4	1.77E-03	4.22E+02	4.14E+02	1.982	
5	2.20E-03	3.25E+02	3.17E+02	2.614	
6	2.80E-03	2.45E+02	2.36E+02	3.486	
7	3.55E-03	1.82E+02	1.78E+02	2.614	
8	4.43E-03	1.38E+02	1.36E+02	0.983	
9	5.64E-03	1.04E+02	1.03E+02	0.495	
10	7.13E-03	7.43E+01	7.88E+01	-5.605	

R: 152. X: 0. Y: 153. DL: 305. REQ: 170. CF: 1.0000
TDHZ ARRAY, 10 DATA POINTS, RAMP: 165.0 MICROSEC, DATA: MK2L
2807 002N 002N Z OPR XTL L 7 10+100
Ch.21 = 0.165 Ch.22 = 0.89 Ch.23 = 15 Ch.24 = 9
RMS LOG ERROR: 1.84E-02, ANTILOG YIELDS 4.3250 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	T 1
P 1	0.05		
P 2	-0.03	0.03	
T 1	-0.06	-0.06	0.97


MK3L
MODEL:
7566.
OHM-M
523. M
3.53
OHM-M
APPARENT RESISTIVITY (OHM-M)
10 4
1000
100
10
1
10 -5
10 -4
0.001
0.01
0.1
TIME (SEC)
Blackhawk Geosciences, Incorporated
% ERROR: 3.56
CALIBRATION: 1
OFFSET: 152. M
RAMP: 165.0

MK3L

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		402.3	1320.0		
7566.26	523.0	-120.7	-396.0	0.1	0.1
3.53					

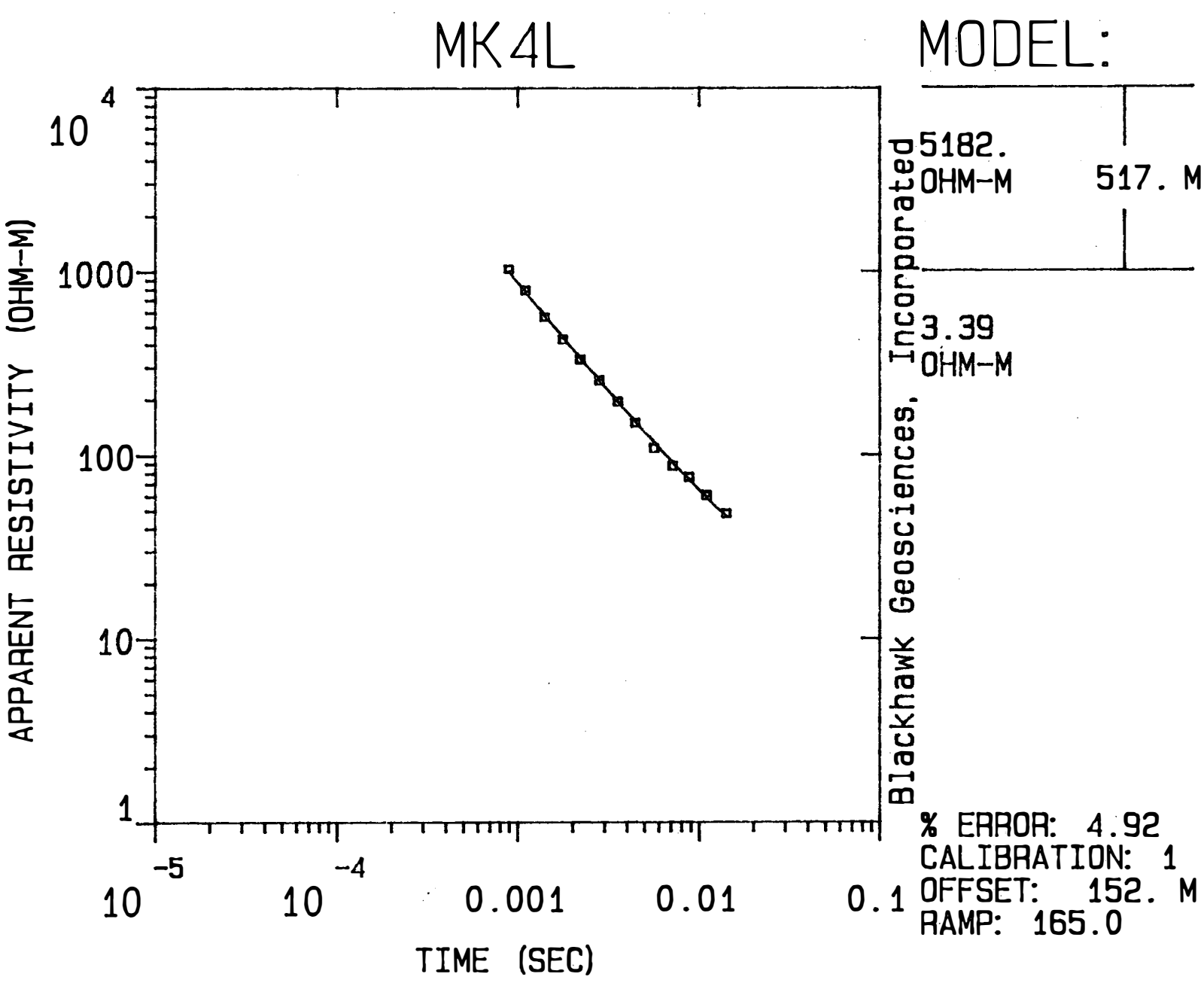
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-04	1.02E+03	1.01E+03	1.304	
2	1.10E-03	7.78E+02	7.77E+02	0.053	
3	1.40E-03	5.65E+02	5.77E+02	-2.068	
4	1.77E-03	4.41E+02	4.36E+02	1.204	
5	2.20E-03	3.40E+02	3.37E+02	1.126	
6	2.80E-03	2.61E+02	2.54E+02	2.892	
7	3.55E-03	1.90E+02	1.94E+02	-1.789	
8	4.43E-03	1.49E+02	1.51E+02	-1.503	
9	5.64E-03	1.10E+02	1.16E+02	-5.092	
10	7.13E-03	9.25E+01	9.01E+01	2.644	
11	8.81E-03	7.13E+01	7.21E+01	-1.162	
12	1.10E-02	5.93E+01	5.77E+01	2.723	

R: 152. X: 0. Y: 153. DL: 305. REQ: 170. CF: 1.0000
TDHZ ARRAY, 12 DATA POINTS, RAMP: 165.0 MICROSEC, DATA: MK3L
2807 002N 003N Z OPR XTL L 7 10+100
Ch.21 = 0.165 Ch.22 = 0.89 Ch.23 = 15 Ch.24 = 9
RMS LOG ERROR: 1.52E-02, ANTILOG YIELDS 3.5560 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.55		
P 2	-0.01	0.99	
T 1	0.00	0.00	1.00
	P 1	P 2	T 1


MK4L
MODEL:
APPARENT RESISTIVITY (OHM-M)
10^4
1000
100
10
1
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
5182.
OHM-M
517. M
3.39
OHM-M
Blackhawk Geosciences, Incorporated
% ERROR: 4.92
CALIBRATION: 1
OFFSET: 152. M
RAMP: 165.0

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		396.2	1300.0		
5181.97	517.4	-121.2	-397.6	0.1	0.1
3.39					

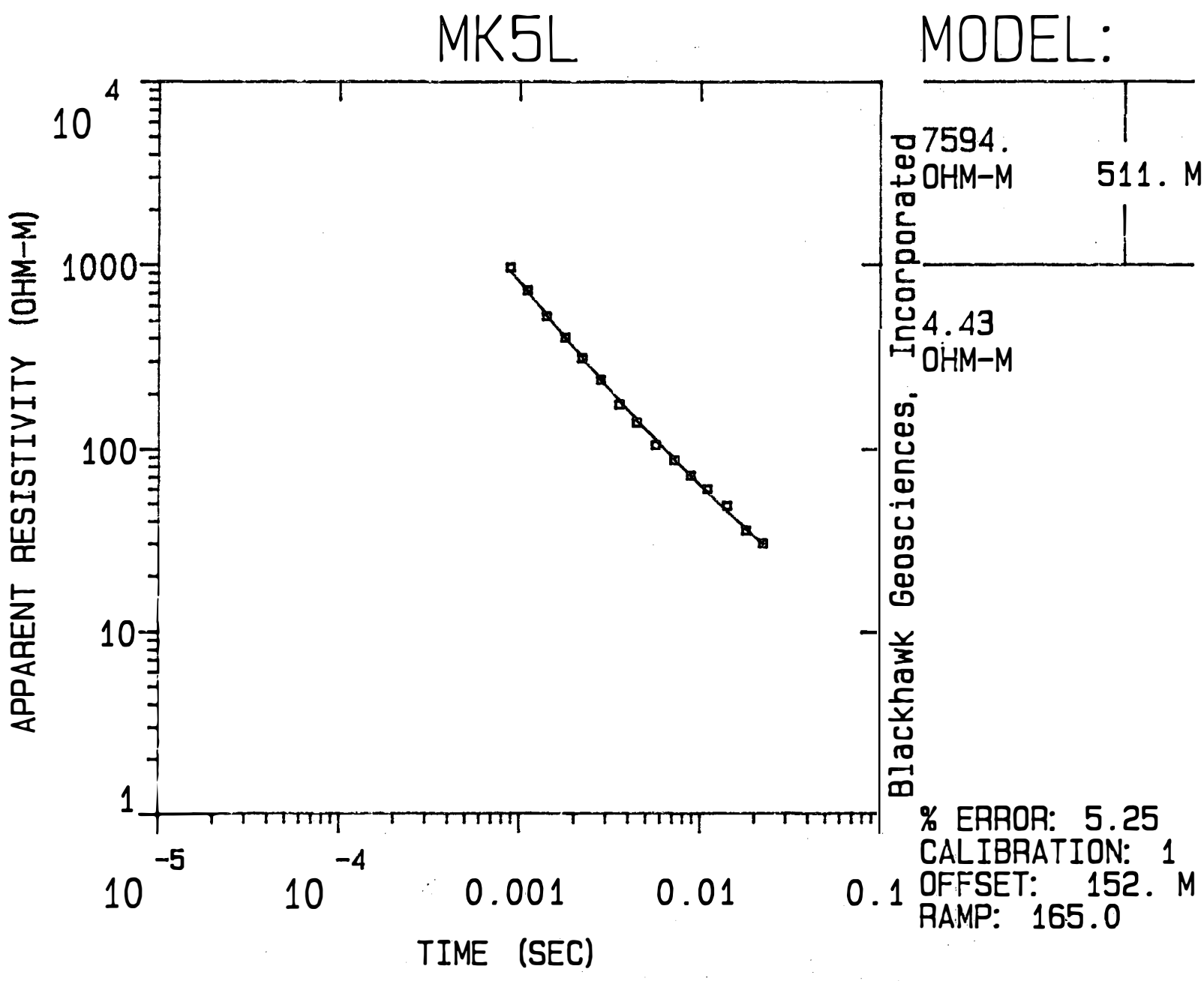
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-04	1.03E+03	9.95E+02	3.280	
2	1.10E-03	7.85E+02	7.65E+02	2.677	
3	1.40E-03	5.62E+02	5.71E+02	-1.457	
4	1.77E-03	4.22E+02	4.31E+02	-1.977	
5	2.20E-03	3.29E+02	3.33E+02	-1.253	
6	2.80E-03	2.53E+02	2.52E+02	0.252	
7	3.55E-03	1.94E+02	1.92E+02	0.640	
8	4.43E-03	1.49E+02	1.51E+02	-1.301	
9	5.64E-03	1.08E+02	1.16E+02	-6.660	
10	7.13E-03	8.69E+01	9.04E+01	-3.774	
11	8.81E-03	7.58E+01	7.29E+01	4.084	
12	1.10E-02	6.01E+01	5.85E+01	2.674	
13	1.41E-02	4.80E+01	4.58E+01	4.674	

R: 152. X: 0. Y: 153. DL: 305. REQ: 170. CF: 1.0000
TDHZ ARRAY, 13 DATA POINTS, RAMP: 165.0 MICROSEC, DATA: MK4L
2807 004N 004N Z OPR XTL L 7 10+100
Ch.21 = 0.165 Ch.22 = 0.89 Ch.23 = 15 Ch.24 = 9
RMS LOG ERROR: 2.09E-02, ANTILOG YIELDS 4.9237 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	T 1
P 1	0.03		
P 2	-0.05	0.09	
T 1	-0.03	-0.03	0.98


MK5L
MODEL:
APPARENT RESISTIVITY (OHM-M)
10^4
1000
100
10
1
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
7594.
OHM-M
511. M
4.43
OHM-M
Blackhawk Geosciences, Incorporated
% ERROR: 5.25
CALIBRATION: 1
OFFSET: 152. M
RAMP: 165.0

MK5L

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		402.3	1320.0		
7593.55	511.3	-109.0	-357.5	0.1	0.1
4.43					

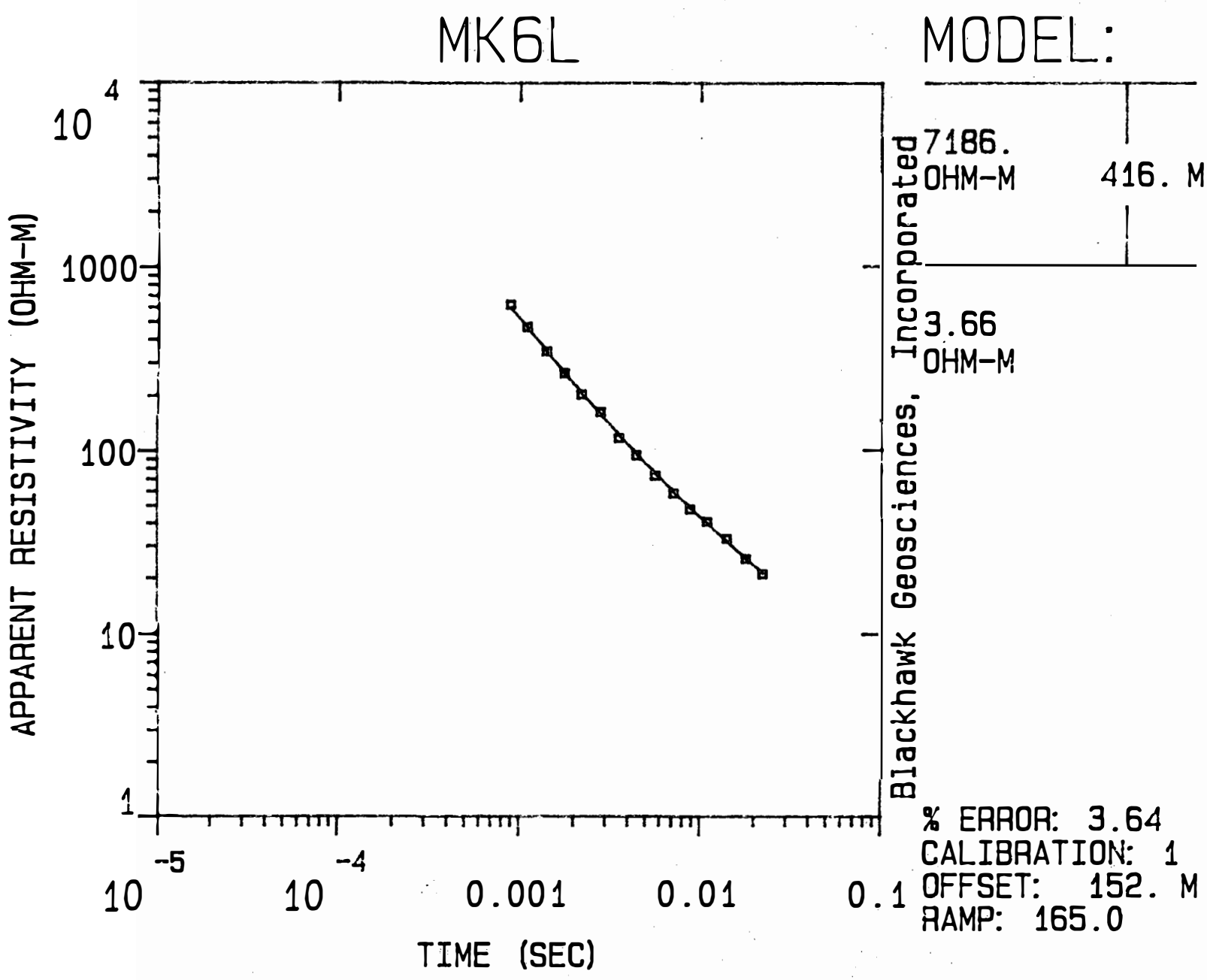
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-04	9.63E+02	9.17E+02	4.987	
2	1.10E-03	7.24E+02	7.09E+02	2.086	
3	1.40E-03	5.24E+02	5.29E+02	-1.028	
4	1.77E-03	4.03E+02	4.02E+02	0.238	
5	2.20E-03	3.11E+02	3.12E+02	-0.430	
6	2.80E-03	2.37E+02	2.38E+02	-0.090	
7	3.55E-03	1.75E+02	1.83E+02	-4.300	
8	4.43E-03	1.39E+02	1.44E+02	-2.926	
9	5.64E-03	1.05E+02	1.12E+02	-5.800	
10	7.13E-03	8.69E+01	8.78E+01	-0.976	
11	8.81E-03	7.15E+01	7.11E+01	0.581	
12	1.10E-02	6.04E+01	5.77E+01	4.670	
13	1.41E-02	4.87E+01	4.53E+01	7.698	
14	1.80E-02	3.56E+01	3.63E+01	-1.954	
15	2.22E-02	3.02E+01	3.00E+01	0.827	

R: 152. X: 0. Y: 153. DL: 305. REQ: 170. CF: 1.0000
TDHZ ARRAY, 15 DATA POINTS, RAMP: 165.0 MICROSEC, DATA: MK5L
2807 005N 005N Z OPR XTL L 7 10+100
Ch.21 = 0.165 Ch.22 = 0.89 Ch.23 = 15 Ch.24 = 9
RMS LOG ERROR: 2.22E-02, ANTILOG YIELDS 5.2541 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	T 1
P 1	0.16		
P 2	-0.16	0.18	
T 1	-0.05	-0.01	0.98


MK6L
MODEL:
7186.
OHM-M
416. M
3.66
OHM-M
% ERROR: 3.64
CALIBRATION: 1
OFFSET: 152. M
RAMP: 165.0
Blackhawk Geosciences, Incorporated
APPARENT RESISTIVITY (OHM-M)
10^4
1000
100
10
1
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)

MK6L

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	(FEET)	CONDUCTANCE (S) LAYER	TOTAL
		332.2	1090.0		
7185.58	415.6	-83.3	-273.4	0.1	0.1
3.66					

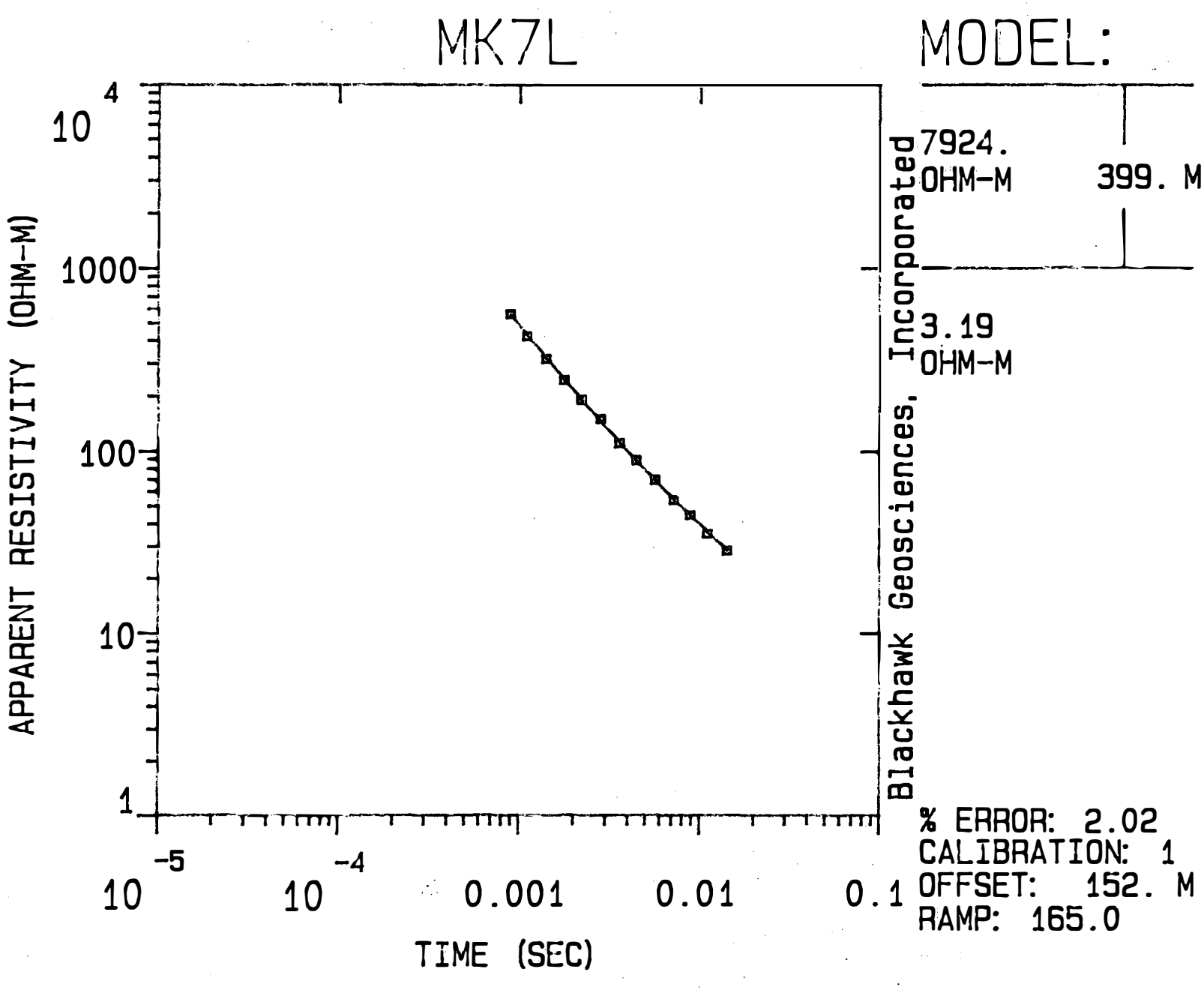
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-04	6.17E+02	5.94E+02	3.849	
2	1.10E-03	4.66E+02	4.60E+02	1.200	
3	1.40E-03	3.43E+02	3.45E+02	-0.461	
4	1.77E-03	2.63E+02	2.63E+02	0.065	
5	2.20E-03	2.02E+02	2.05E+02	-1.759	
6	2.80E-03	1.62E+02	1.57E+02	3.213	
7	3.55E-03	1.17E+02	1.22E+02	-3.484	
8	4.43E-03	9.43E+01	9.61E+01	-1.923	
9	5.64E-03	7.29E+01	7.51E+01	-2.839	
10	7.13E-03	5.86E+01	5.96E+01	-1.778	
11	8.81E-03	4.79E+01	4.86E+01	-1.479	
12	1.10E-02	4.08E+01	3.98E+01	2.629	
13	1.41E-02	3.30E+01	3.16E+01	4.281	
14	1.80E-02	2.56E+01	2.56E+01	-0.014	
15	2.22E-02	2.11E+01	2.13E+01	-1.330	

R: 152. X: 0. Y: 153. DL: 305. REQ: 170. CF: 1.0000
TDHZ ARRAY, 15 DATA POINTS, RAMP: 165.0 MICROSEC, DATA: MK6L
2907 006N 006N Z OPR XTL L 7 10+100
Ch.21 = 0.165 Ch.22 = 0.89 Ch.23 = 15 Ch.24 = 9
RMS LOG ERROR: 1.55E-02, ANTILOG YIELDS 3.6404 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.14		
P 2	-0.17	0.22	
T 1	-0.05	0.00	0.98
	P 1	P 2	T 1


MK7L
MODEL:
7924.
OHM-M
399. M
3.19
OHM-M
APPARENT RESISTIVITY (OHM-M)
10^4
1000
100
10
1
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
Blackhawk Geosciences, Incorporated
% ERROR: 2.02
CALIBRATION: 1
OFFSET: 152. M
RAMP: 165.0

MK7L

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	(FEET)	CONDUCTANCE (S) LAYER	TOTAL
		338.3	1110.0		
7923.82	398.5	-60.2	-197.6	0.1	0.1
3.19					

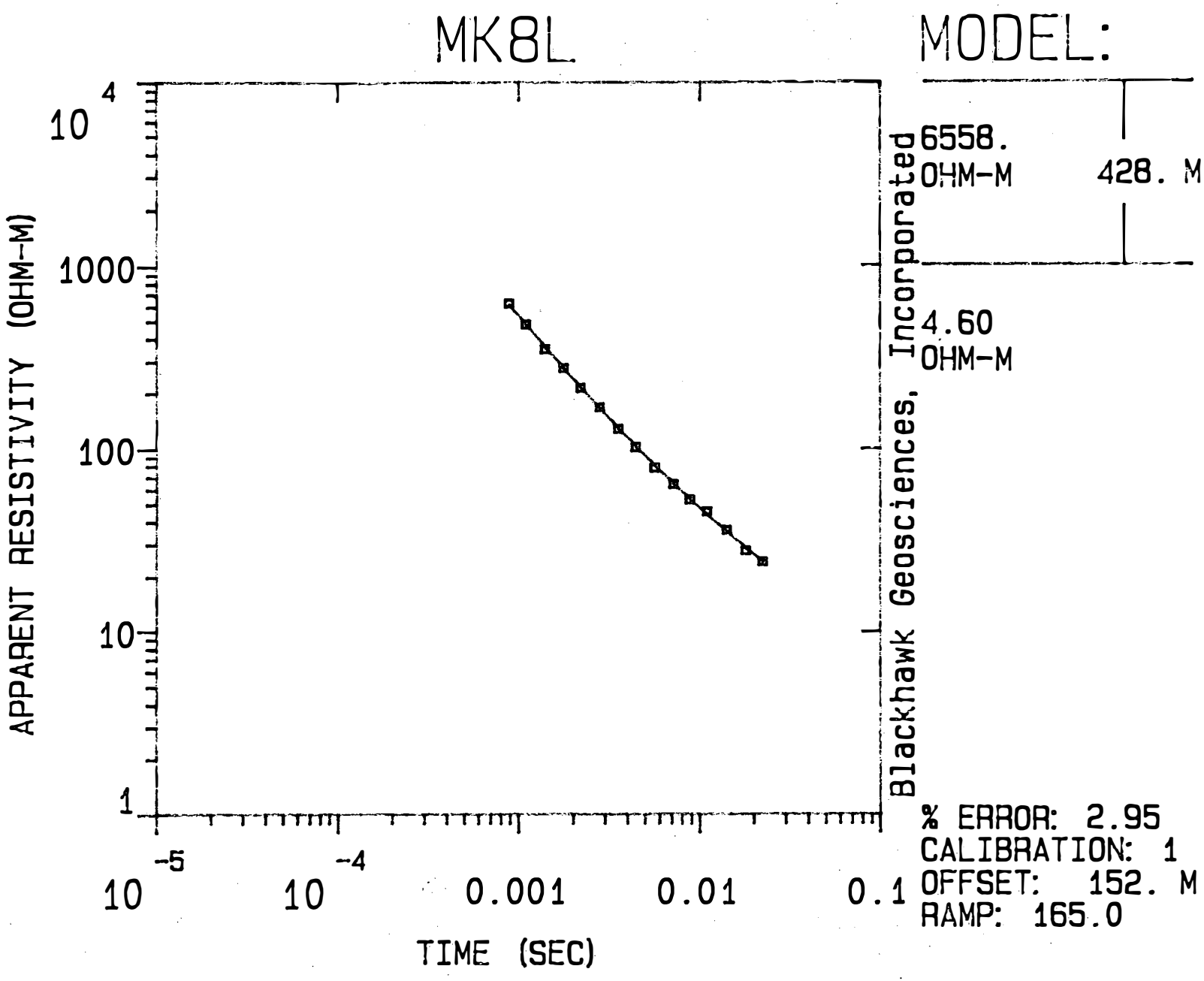
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-04	5.58E+02	5.55E+02	0.558	
2	1.10E-03	4.21E+02	4.29E+02	-1.756	
3	1.40E-03	3.17E+02	3.21E+02	-1.191	
4	1.77E-03	2.43E+02	2.44E+02	-0.436	
5	2.20E-03	1.91E+02	1.90E+02	0.168	
6	2.80E-03	1.50E+02	1.45E+02	3.125	
7	3.55E-03	1.11E+02	1.12E+02	-0.982	
8	4.43E-03	8.95E+01	8.85E+01	1.152	
9	5.64E-03	6.98E+01	6.90E+01	1.060	
10	7.13E-03	5.42E+01	5.46E+01	-0.585	
11	8.81E-03	4.47E+01	4.44E+01	0.632	
12	1.10E-02	3.55E+01	3.62E+01	-2.073	
13	1.41E-02	2.86E+01	2.86E+01	0.135	

R: 152. X: 0. Y: 153. DL: 305. REQ: 170. CF: 1.0000
TDHZ ARRAY, 13 DATA POINTS, RAMP: 165.0 MICROSEC, DATA: MK7L
2907 007N 007N Z OPR XTL L 7 10+100
Ch.21 = 0.165 Ch.22 = 0.89 Ch.23 = 15 Ch.24 = 9
RMS LOG ERROR: 8.69E-03, ANTILOG YIELDS 2.0202 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

	P 1	P 2	T 1
P 1	0.08		
P 2	-0.10	0.14	
T 1	-0.04	-0.01	0.98


MK8L
MODEL:
6558.
OHM-M
428. M
4.60
OHM-M
Blackhawk Geosciences, Incorporated
% ERROR: 2.95
CALIBRATION: 1
OFFSET: 152. M
RAMP: 165.0
APPARENT RESISTIVITY (OHM-M)
10^4
1000
100
10
1
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)

MK8L

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	ELEVATION (FEET)	CONDUCTANCE (S) LAYER	CONDUCTANCE (S) TOTAL
		341.4	1120.0		
6558.17	428.2	-86.8	-284.8	0.1	0.1
4.60					

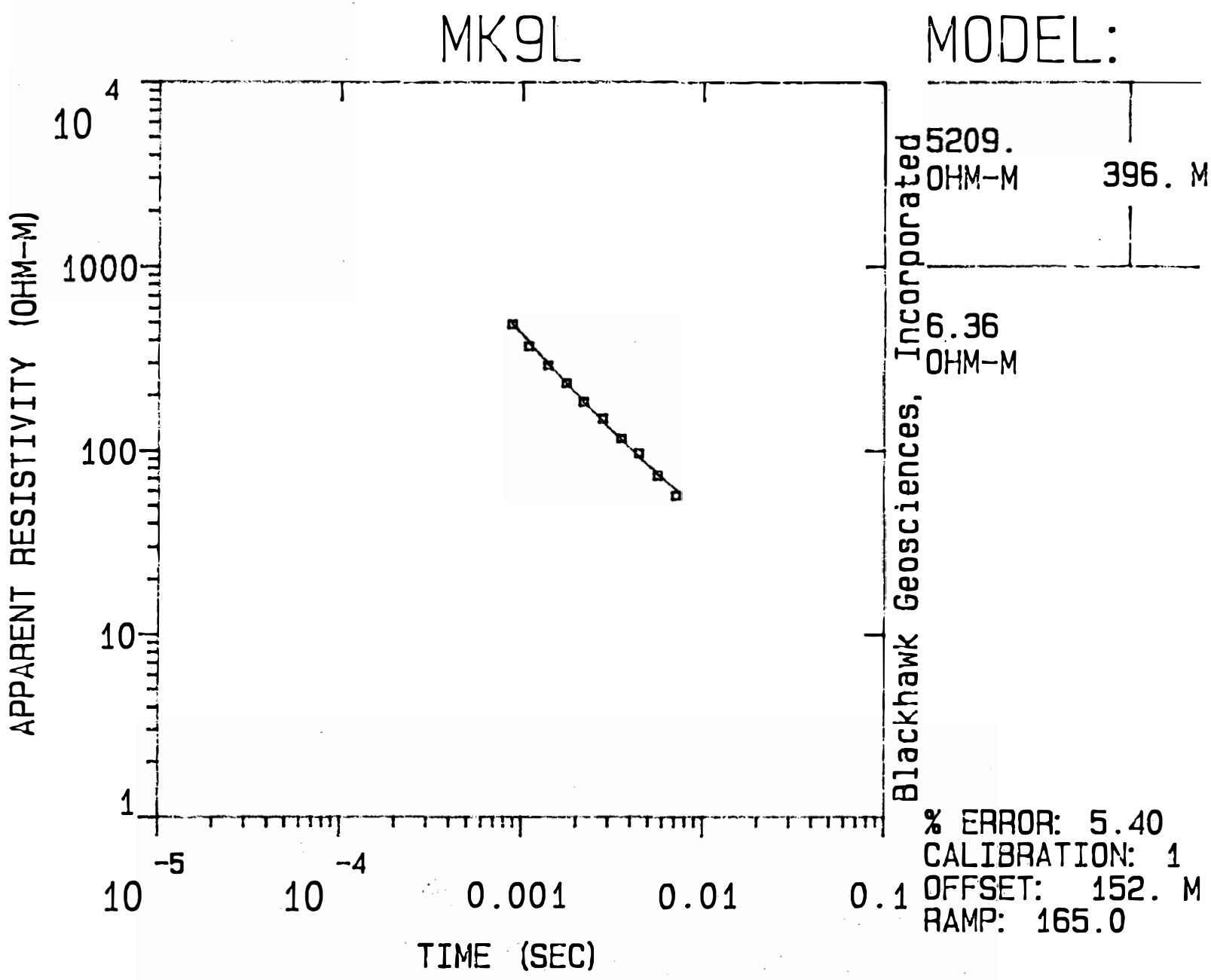
	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-04	6.21E+02	6.10E+02	1.940	
2	1.10E-03	4.78E+02	4.74E+02	0.774	
3	1.40E-03	3.49E+02	3.57E+02	-2.371	
4	1.77E-03	2.75E+02	2.73E+02	0.763	
5	2.20E-03	2.13E+02	2.14E+02	-0.511	
6	2.80E-03	1.67E+02	1.65E+02	1.519	
7	3.55E-03	1.27E+02	1.28E+02	-1.043	
8	4.43E-03	1.01E+02	1.02E+02	-0.992	
9	5.64E-03	7.82E+01	8.02E+01	-2.519	
10	7.13E-03	6.37E+01	6.42E+01	-0.805	
11	8.81E-03	5.25E+01	5.28E+01	-0.453	
12	1.10E-02	4.53E+01	4.34E+01	4.278	
13	1.41E-02	3.58E+01	3.49E+01	2.575	
14	1.80E-02	2.76E+01	2.85E+01	-3.077	
15	2.22E-02	2.40E+01	2.39E+01	0.227	

R: 152. X: 0. Y: 153. DL: 305. REQ: 170. CF: 1.0000
TDHZ ARRAY, 15 DATA POINTS, RAMP: 165.0 MICROSEC, DATA: MK8L
3007 008N 008N Z OPR XTL L 7 10+100
Ch.21 = 0.165 Ch.22 = 0.89 Ch.23 = 15.5 Ch.24 =
RMS LOG ERROR: 1.26E-02, ANTILOG YIELDS 2.9525 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.06		
P 2	-0.01	0.95	
T 1	0.00	0.00	1.00
	P 1	P 2	T 1


MK9L
MODEL:
APPARENT RESISTIVITY (OHM-M)
10^4
1000
100
10
1
10^-5
10^-4
0.001
0.01
0.1
TIME (SEC)
5209.
OHM-M
396. M
6.36
OHM-M
Blackhawk Geosciences, Incorporated
% ERROR: 5.40
CALIBRATION: 1
OFFSET: 152. M
RAMP: 165.0

MK9L

MODEL: 2 LAYERS

RESISTIVITY (OHM-M)	THICKNESS (M)	ELEVATION (M)	(FEET)	CONDUCTANCE (S) LAYER	TOTAL
		353.6	1160.0		
5209.06	395.9	-42.4	-139.0	0.1	0.1
6.36					

	TIMES	DATA	CALC	% ERROR	STD ERR
1	8.90E-04	4.85E+02	4.91E+02	-1.086	
2	1.10E-03	3.68E+02	3.84E+02	-4.225	
3	1.40E-03	2.89E+02	2.93E+02	-1.617	
4	1.77E-03	2.31E+02	2.27E+02	1.671	
5	2.20E-03	1.82E+02	1.80E+02	0.656	
6	2.80E-03	1.48E+02	1.41E+02	4.567	
7	3.55E-03	1.15E+02	1.12E+02	2.913	
8	4.43E-03	9.57E+01	9.08E+01	5.391	
9	5.64E-03	7.19E+01	7.31E+01	-1.629	
10	7.13E-03	5.60E+01	5.96E+01	-6.044	

R: 152. X: 0. Y: 153. DL: 305. REQ: 170. CF: 1.0000
TDHZ ARRAY, 10 DATA POINTS, RAMP: 165.0 MICROSEC, DATA: MK9L
3007 009N 009N Z OPR XTL L 7 10+100
Ch.21 = 0.165 Ch.22 = 0.89 Ch.23 = 15.5 Ch.24 =
RMS LOG ERROR: 2.28E-02, ANTILOG YIELDS 5.4014 %
LATE TIME PARAMETERS

* Blackhawk Geosciences, Incorporated *

PARAMETER RESOLUTION MATRIX:
"F" MEANS FIXED PARAMETER

P 1	0.71		
P 2	0.00	1.00	
T 1	0.00	0.00	1.00
	P 1	P 2	T 1